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Courtship Leading to Copulation in the Cloudless Sulphur, *Phoebis sennae* (Pieridae)

Ronald L. Rutowski

Department of Zoology, Arizona State University, Tempe, AZ 85287

Abstract. The components and temporal structure of courtship leading to copulation are described for the cloudless sulphur, *Phoebis sennae* Linnaeus. Hand-reared virgin females were tethered and placed near a nectar source to elicit male interest and courtship behavior. The courtship is like that described for several other pierids in that the male buffets the female with his wings for a few seconds before alighting and attempting copulation. Females either remain motionless or may perform a brief rejection behavior before becoming motionless and accepting the male.

Introduction

During copulation, a male butterfly passes accessory gland secretions into the female's reproductive tract and these secretions are used by the female for her own nutritional purposes (Boggs, 1981; Boggs and Gilbert, 1979; Boggs and Watt, 1981). Rutowski *et al.* (1983) described the interspecific variation in the size of this nutrient investment made by males for ten species of butterflies. It was argued in that paper that the males of these ten species do not vary substantially in the size of the investment and that this is correlated with a lack of variation in their courtship behavior. In particular the investment does not appear to vary between species in a way that reflects differences in the intensity of mate choice from species to species. This paper is one in a series describing the previously unknown courtships of species whose nutrient investments were discussed. In particular this paper describes the courtship behavior leading to copulation for the cloudless sulphur, *Phoebis sennae* Linnaeus.

Methods

The cloudless sulfur was studied from July to November of 1981 at the Archbold Biological Station 13 km south of Lake Placid, Florida. Virgin females were reared from larvae collected in the field from the coffee sennae, *Cassia occidentalis* Linnaeus. Rearing techniques and conditions were like those described for *Eurema lisa* Boisduval and LeConte in Rutowski (1977). Within 2 days after eclosion females were tethered and placed on an exposed perch in or near a large planting of pagoda flower (*Clerodendrum paniculatum* Linnaeus) that was regularly visited by males and females of *P. sennae*. A tether constituted a 1 m long piece of cotton thread, one end tied around the base of the female's abdomen and the other end to a nearby plant. Interactions leading to copulation between these virgins and males were filmed using a Beaulieu 4008 ZM 2 super-8 movie camera at the 24 (most interactions) and 70 (a few interactions) frame per sec settings. All summary statistics are given as mean ± standard deviation.

Results

Twenty-one courtships leading to copulation were filmed using 5 virgin females. As many as 6 copulations with a single female were obtained by separating the pair as soon as possible after coupling and then returning the female to the perch and permitting her to mate again. Of the 21 film records three involved courtships with more than one male and so were disregarded in these analyses. Another was also disregarded because the female changed perch during the courtship and although she was followed with the camera it was not possible from the film to see the necessary details.

Courtship began when the male approached the female and made contact with her wings with either his wings or legs, or when the female responded to the male approach by opening her wings either briefly in a wing flick or for some time in a mate refusal posture (Obara, 1964). In only three courtships did the female not open her wings at some time during the interaction. If the female assumed a mate refusal posture it was not uncommon for the male to land on the female's wings. After this or before the male alit the female closed her wings and the male moved into position along side the female with his head pointing in the same direction as the female's. The male then curled his abdomen out from between his wings which were flapping throughout this time and began attempting to insert his abdomen up between the female's hindwings. Coupling could not be directly observed but its occurrence was assumed to be accompanied by a cessation of wing flapping by the male. However, within a second or two after the male closed his wings he began strong wing beats and initiated a post-nuptial flight in which he attempted to carry the female to another perch. In all cases, however, the tether obviously prevented the male from carrying out his intentions.

In 5 courtships the male's first attempt to couple was unsuccessful as indicated by the fact that he stopped probing at the female's hindwings with his abdomen and shifted to the other side of the female before probing again. In four of these instances the second coupling attempt was successful while in one the male was not successful until his third attempt.

For purposes of temporal summary the beginning of courtship was taken as when the female opened her wings in response to the male's approach or when the male first made contact with the female, which ever came first. The end of courtship was taken as when the male closed his wings and became still or, if he did not do that when he began the strong wing beats that marked the beginning of the post-nuptial flight. The mean duration of all filmed courtships then was 6.87 ± 4.65 sec ($n = 17$; range = 2.96 - 22.3). The large standard deviation reflects the pooling of courtships that varied in structure. For example, for courtships in which the male successfully coupled in his first attempt and in which the female did not perform a mate refusal posture the duration was 4.83 ± 1.26 sec ($n = 8$; range = 3.5 - 6.58 sec). Also, courtships in which the male performed more than one copulation attempt but in which the female did not have her wings open for more than 2 sec total during the courtship were of significantly greater duration (7.43 ± 1.28 sec ($n = 4$); $\underline{t}$ 3.71, 12 df, $p < 0.002$) by 2 to 3 sec than courtships in which the male attempted copulation only once.

The responses of females to males varied from remaining still with the wings closed to strong and prolonged mate refusal postures. In one courtship the female performed a mate refusal posture for more than 7 sec during the courtship. However, in most (65%) the female performed a flutter response or mate refusal posture that lasted less than 2 seconds. Obviously the duration of courtship is to some extent affected by the amount of time the female has the wings open during the courtship but it was not statistically demonstrable with this data set. However, the two longest courtships were also those in which females performed lengthy mate refusal postures but also those in which the male attempted copulation 2 or 3 times.

Contact by the male or wing opening by the female were convenient and clear markers of the beginning of courtship but in a variety of cases the male hovered for a second or so over the female before he touched her or the female responded. This hovering appeared similar to what the male does when courting flying females before they alight.

Unsuccessful courtships took one of two forms with perched females. In the first, the male departs although the female has assumed an apparently receptive posture with the wings closed. In the second the male is prevented from attaining copulation by the female who persistently performs a mate refusal posture and he finally departs. This was observed a number of times even with the hand-reared virgin females. The male's response to this posture was usually to land on the dorsal wing surfaces and move around in an attempt to attain the position required to couple.

Discussion

The courtship of *Phoebis sennae* is strikingly similar in form and temporal structure to that described for several other pierids including *Eurema lisa* (Rutowski, 1978), *Colias eurytheme* Boisduval, *C. philodice* Godart (Silberglied and Taylor, 1978), *Pieris protodice* Linnaeus (Rutowski, 1979), and several members of the genus *Pieris* that occur in Japan (Suzuki *et al.*, 1977). In all these species, the typical pattern is that the male approaches a perched female and buffets her with his wings briefly before alighting and attempting to couple with her. If the female is flying and receptive when the male approaches she alights quickly and courtship proceeds as described. In some pierids the male performs a special display before attempting to couple with the female (*Eurema daira* Latreille: wing waving display (Rutowski, in press); *Nathalis iole* Boisduval: wing spread display (Rutowski, 1981(83)). Although displays of this sort were not observed in successful courtship in *P. sennae* the overall courtship durations were not substantially different from those observed in species with these displays. Hence, as suggested in Rutowski *et al.* (1983) the courtship of this species does not depart in overall structure and complexity from that observed in most species of butterflies (see Silberglied, 1977; Scott, 1973).

Among the species of *Phoebis* that are sympatric in the neotropics there are striking differences in the structure of the supposed scent-producing structures (Klots, 1951, pers. obs.) and in the patterns of ultraviolet reflectance found on the male's dorsal wing surface (Allyn and Downey, 1977; Silberglied, 1979). *Phoebis sennae* males have no ultraviolet reflectance and a very indistinct sex brand. It would be of interest to determine if the variation in ultraviolet reflectance patterns and scent-producing structures found in these sulphurs are correlated in any way with variation in courtship behavior.

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